Solar Energy Technologies Program Multi-Year Technical Plan Review Presentation

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.

Solar Energy Systems Symposium
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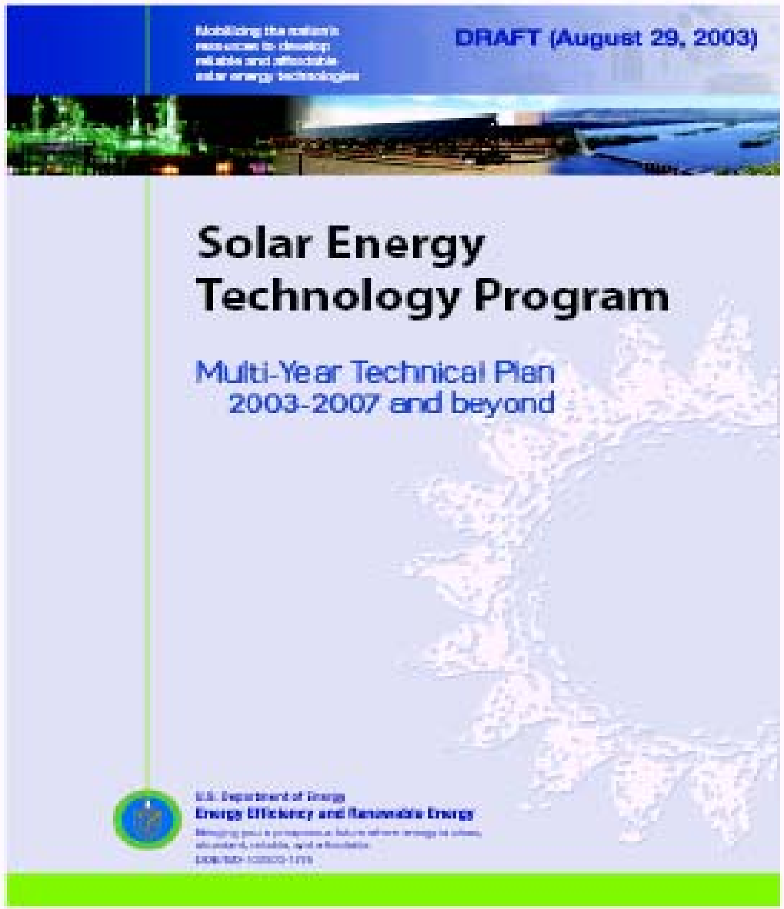
First Integrated Solar MYTP



http://www.nrel.gov/extranet/techplan/techplan.html

Solar MYTP "Team"

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Multi-Year Plan Outline

Section 1.0

National Perspective

Section 2.0

Industry, Markets, Applications

Section 3.0

Systems-Driven Approach

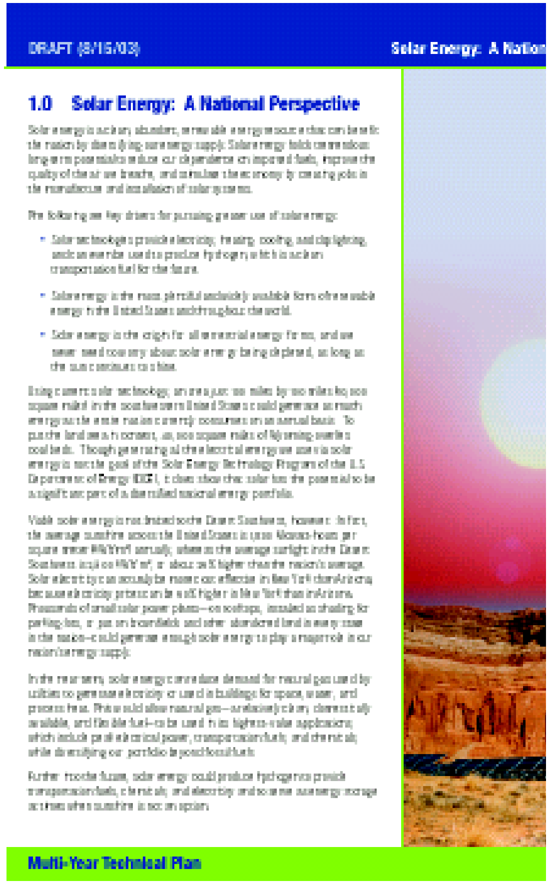
Section 4.0

Technical Sections

Section 5.0

Managing the Solar Energy Program

1.0 National Perspective


DRAFT (8/15/03) Solar Energy: A Nation

1.0 Solar Energy: A National Perspective

Multi-Year Technical Plan


Solar Energy: A National Perspective

R&D 100 Awards

Near-Term Goals:

Long-Term Goals:

Strategy

Solar Energ


Solar Energy: A National Perspective DRAFT (8/15/03)

Solar Power Goes Mainstream

Solar Energy Technology Program

2.0 Industry, Markets, and Applications

Major Themes:

Table 2-1. Solar Technologies and their Applicability to Various Market Sectors

		Distributed Energy: Building-Integrated	Distributed Energy: Ground-Mounted	Distributed Energy: Off-Grid	Central Generation	Fuels and Chemicals
PV	One-Sun	● Electrical Generation	● Electrical Generation	● Electrical Generation	● Electrical Generation	● Transportation
PV	Concentrating		● Electrical Generation	● Electrical Generation	● Electrical Generation	● Transportation
Thermal	Dishes		● Electrical Generation	● Electrical Generation	● Electrical Generation	● Transportation
Thermal	Towers				● Electrical Generation	● Transportation
Thermal	Troughs	● Electrical Generation ● Thermal	● Electrical Generation ● Thermal		● Electrical Generation	
Thermal	One-Sun Thermal	● Thermal	● Thermal	● Thermal		
Thermal	Air[a]	● Thermal				
Thermal	Passive Solar[a]	● Thermal				
	Hybrid Lighting	● Solar Lighting				

[a]DOE Solar Energy Technology Program does not conduct research in thermal air and passive solar collectors, and these technologies are not discussed further in this plan.

● Electrical Generation ● Thermal ● Solar Lighting ● Transportation

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•Solar Systems Descriptions and Requirements

3.0 Systems Driven Approach

What is the Systems Driven Approach?

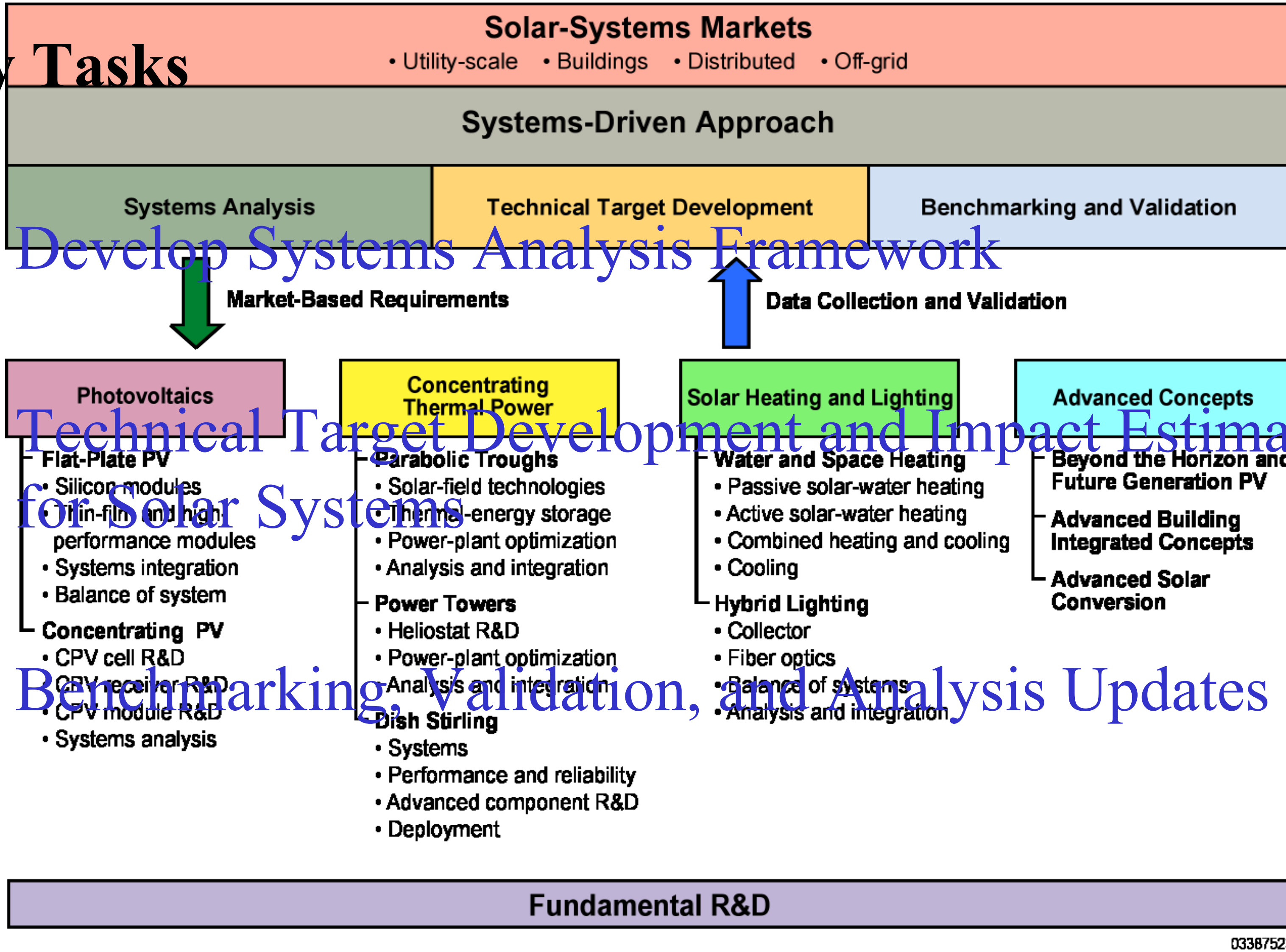
Definition:

All technical targets for R&D on the components and systems funded through the Solar Energy Technology Program are derived from a common market perspective and national energy goals, and the resultant technologies are tested and validated in the context of established criteria for each market.

3.0 Systems Driven Approach

Key Tasks

- Develop Systems Analysis Framework
- Technical Target Development and Impact Estimates for Solar Systems
- Benchmarking, Validation, and Analysis Updates

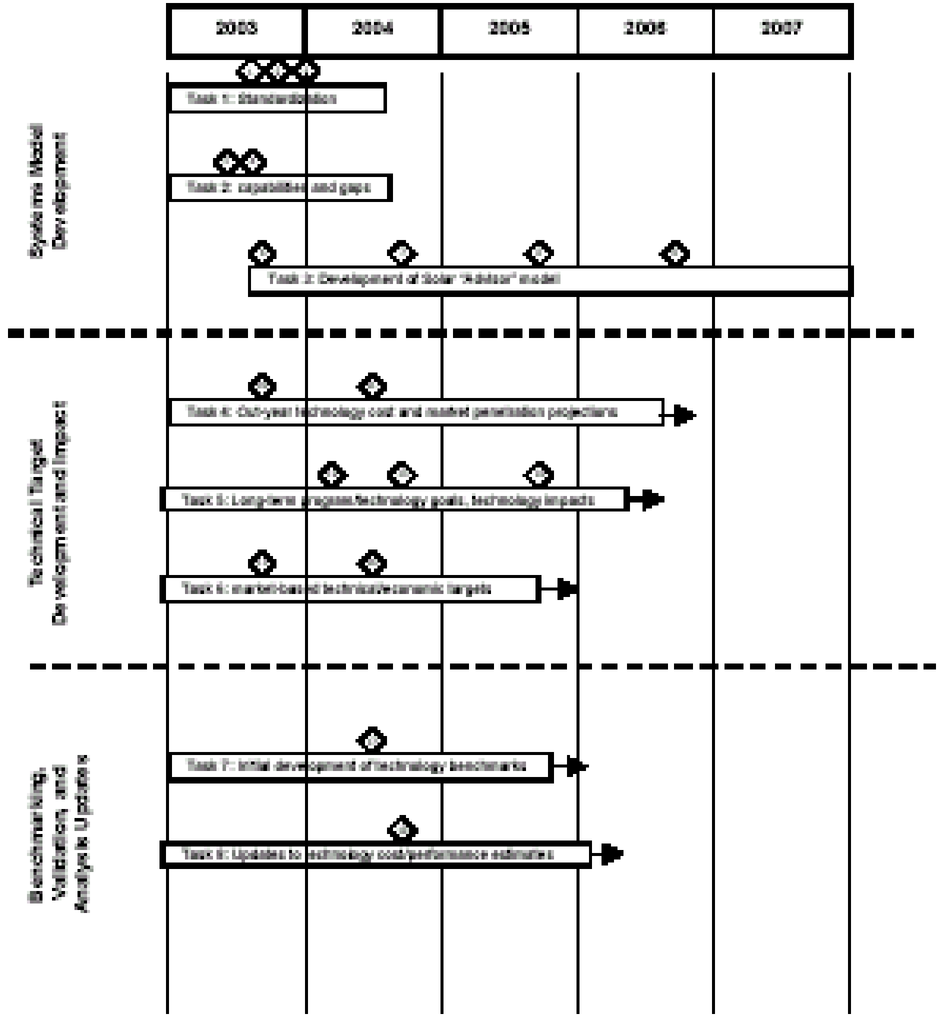


3.0 Systems Driven Approach

Table 3-1. Tasks for Systems-Driven Approach Development and Implementation

Task	Title	Barriers
I	**Systems Model Development**	
1	**Standardization of assumptions and requirements** • Develop standard technology configurations • Develop technology benchmark input requirements • Develop standard financial/economic assumptions for baseline configurations	E,D
2	**Identification of analysis capabilities and gaps** • Identify existing program/technology analysis capabilities • Identify existing or recommend development of new market-based systems models • Identify solar resource data requirements necessary to support SDA systems-analysis efforts	A
3	**Development of Solar "ADVISOR" model** • Select candidate market(s) for near-term development of analysis tool • Develop analysis tools for remaining markets identified in the Solar Program Multi-Year Technical Plan. • Develop integrated Solar "ADVISOR" model based on integration of market-based tools	A

3.0 Systems Driven Approach



Legend

Milestones

1. Develop standard technology configurations
2. Develop technology benchmark input requirements
3. Develop standard financial/economic assumptions for baseline configurations
4. Identify existing program/technology analysis capabilities
5. Identify existing or recommend development of new market-based systems analysis platforms
6. Select candidate market(s) for near-term development of integrated analysis platforms
7. Demonstrate beta version of 1-3 integrated solar analysis platforms for selected markets
8. Demonstrate beta versions of integrated solar analysis platforms for remaining market sectors
9. Demonstrate integrated analysis platform for integrated market sectors
10. Identify out-year technology cost projections based on existing program/technology documents (roadmaps, program plans, etc...)
11. Conduct rigorous due-diligence like review of out-year projections (not including troughs/towers)
12. Align program/technology goals with EERE and National goals and interests (i.e. conservation, infrastructure, energy supply, environment, security)
13. Complete initial analysis estimating long-term benefits that are aligned with National goals and interests
14. Complete trade-off studies identifying highest impact technologies for each market sector
15. Identify high-level market-specific technical/economic measures of success for each technology (i.e. LCOE, payback, first cost)
16. Complete development of initial system level technical/economic targets for each high-level MOS
17. Document cost, performance, and reliability FY03 benchmarks for each CSET technology based on standardized assumptions
18. Define parameters of program-wide cost, performance, and reliability data collection requirements

4.0 Technical Sections

General Outline

1.0 Technology Systems Status

2.0 Technology and Component Goals and Objectives

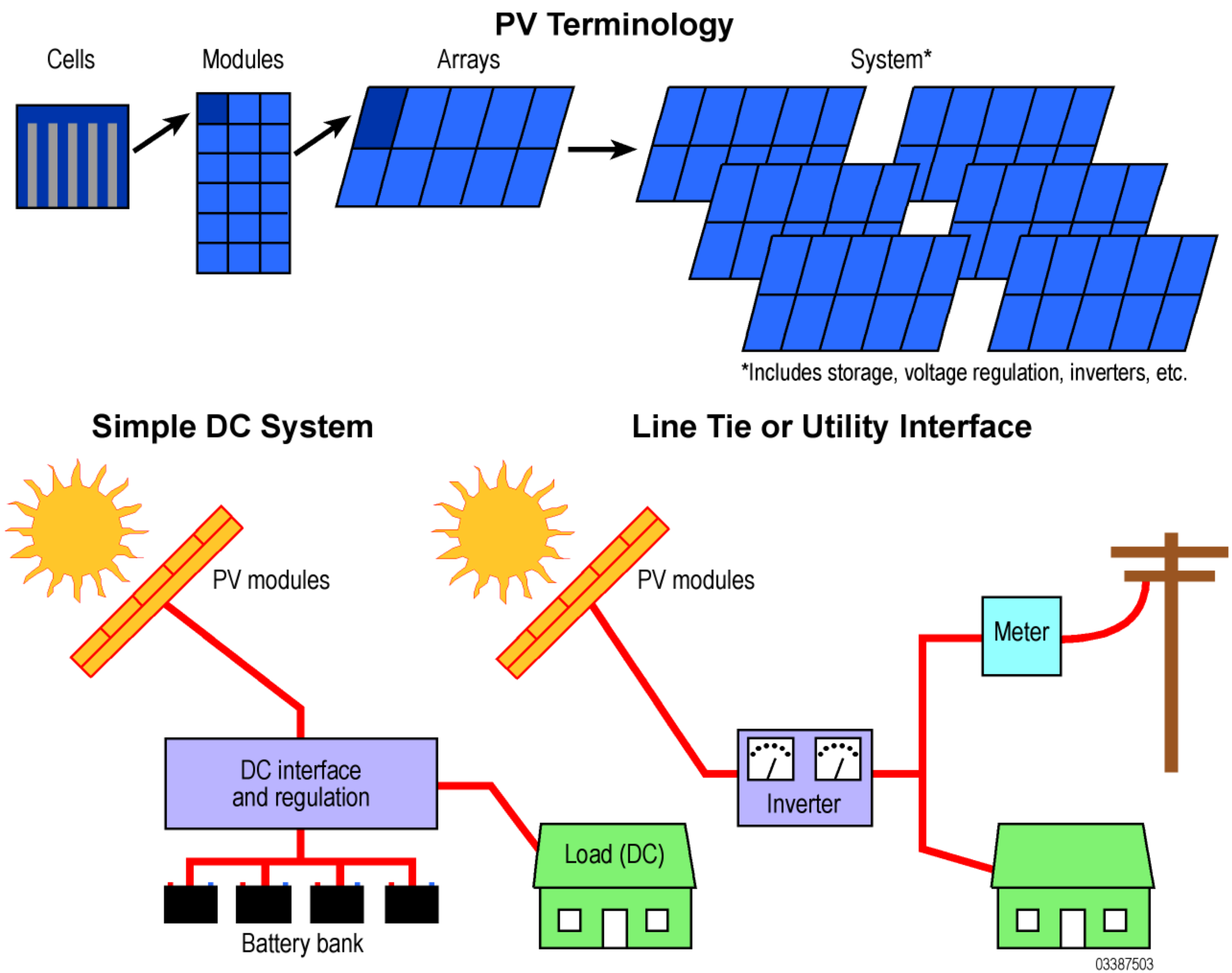
3.0 Key Technical Challenges

4.0 Technical Barriers

5.0 Technical Approach and Tasks

6.0 Schedule and Milestones

4.1.1 Photovoltaic Systems



4.1.1 Photovoltaic Systems

Goals:

Assist industry in developing PV systems that can provide quality performance and reliability at acceptable costs to the consumers.

Acceptable costs are determined by a number of factors and will be fine-tuned as part of the continuing analysis, target setting, and validation conducted within the context of the ongoing systems-driven approach.

4.1.1 Photovoltaic Systems

U.S. Department of Energy
Energy Efficiency and Renewable Energy

Tasks for Flat Plate PV Modules

1. Basic Science
2. Crystalline Silicon: cell and device improvements
3. Crystalline Silicon: module improvements
4. Thin Films and High Performance: materials and device improvements
5. Thin Films: module improvements
6. Modules: crosscutting activities

Tasks for Flat Plate PV Systems and Balance of Systems

7. Systems Analysis
8. System Benchmarking and Validation
9. PV System Performance and Standards
10. PV Technology Adoption
11. Inverter Testing and Industry Support
12. High-Reliability Inverter Initiative
13. Inverter R&D 5-year Plan
14. Charge Controller and Battery Improvements

Table 4.1.1-2. Targets for Flat-Plate PV Systems in Residential Applications (2–3-kW grid-tied example)

System Element	Units	2003	2007	2020
Design	$\$/W_{ac}$	0.25	0.15	0.10
Module Price	$\$/W_{dc}$	4.80	2.50	1.00–1.50
Direct cost/power	$\$/W_p$	3.00	1.65	0.33–0.50
Conversion efficiency	%	14	[illegible]	19–20
Direct cost/area	$\$/m^2$	420	15	50–100
Inverter Price	$\$/W_{ac}$	1.10	0.50	0.30
DC-AC conversion efficiency	%	94	96	97
Replacement	Years	5	10	20
Other BOS	$\$/W_{ac}$	0.85	0.60	0.40
Installation	$\$/W_{ac}$	2.45	1.50	0.50
INSTALLED SYSTEM PRICE	$\$/W_{ac}$	6.25–9.45*	5.25	2.30–2.80
System Efficiency	%	11.5	14	16
Lifetime	Years	20	20	30
Degradation	%/Yr	1–2	1-2	1
O&M cost	$\$/kWh_{ac}$	0.08	0.02	0.005
LEVELIZED ENERGY COST	$\$/kWh_{ac}$	0.25–0.40*	0.22	0.8–0.10

Considerations:
LEC is cost to consumer.
2003 numbers taken from example of Figure 4.1.1-3.
LEC is dependent on solar resource (2000 kWh/m2/yr assumed here).
2003 data assume retrofit market; 2007 and 2020 are for new construction.
O&M primarily based on one inverter replacement every 5 years for 2003 figures; every 10 years for 2010 and 2020 figures.
*The ranges reflect the variability in calculations including various incentives and financing assumptions. LECs have been reported previously for year 2000 with incentives included.

4.1.2 Concentrator Photovoltaic Systems

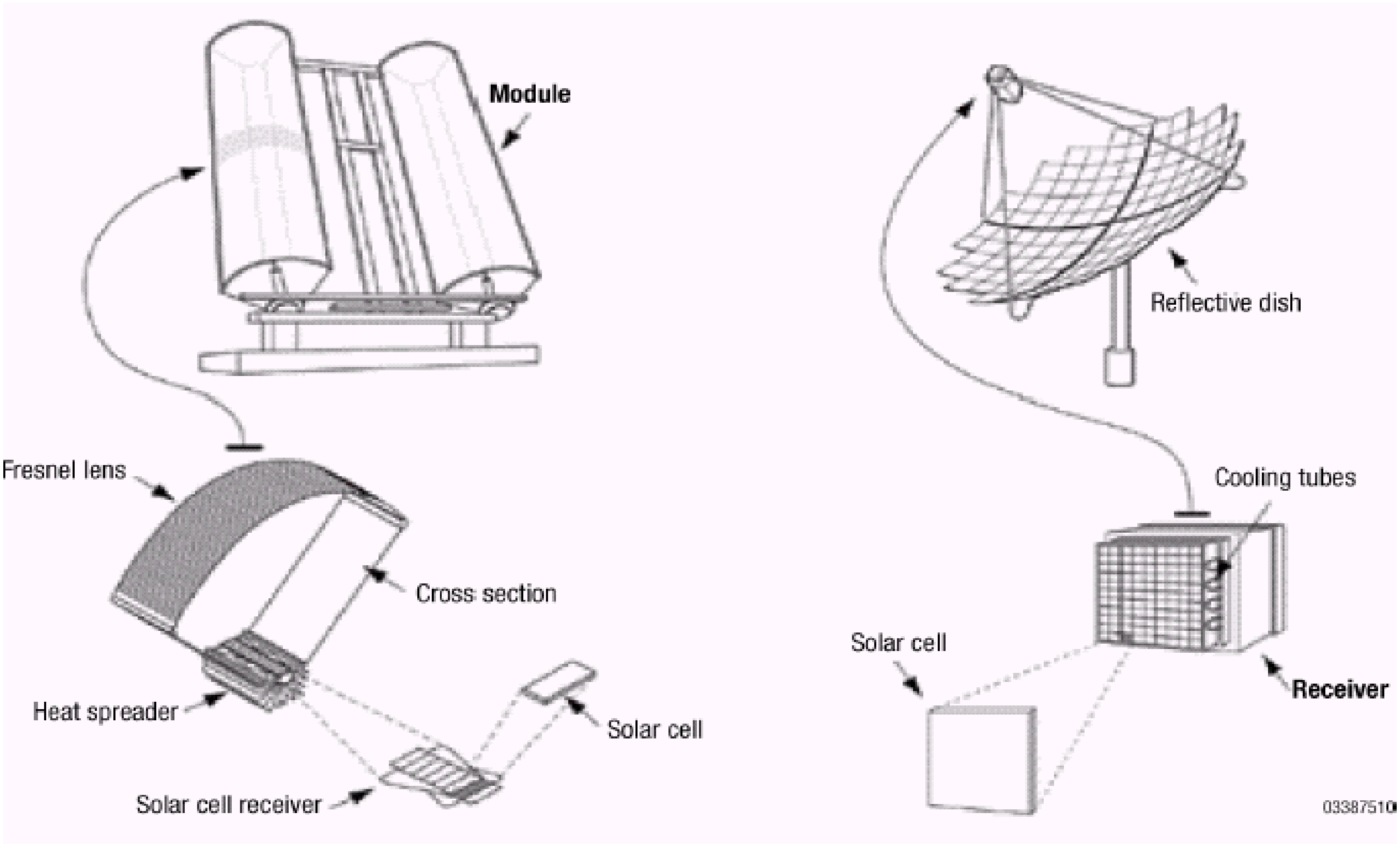


Figure 4.1.2-3. Schematic of a linear-focus Fresnel lens concentrator PV system.

Figure 4.1.2-4. Schematic of a point-focus dish concentrator PV system.

4.1.2 Concentrator Photovoltaic Systems

Goals:

Develop viable concentrator photovoltaic technologies for application in a wide range of electrical markets, particularly for the distributed generation and larger bulk electric utility markets.

The target electricity cost is 4 to 6 cents/kWh by 2020.

4.1.2 Concentrator Photovoltaic Systems

Table 4.1.2-1. Technical Targets for CPV Technologies

System Element	Units	2003 (baseline)	2007	2025
Solar resource	kWh/m^2-yr	2400	2400	2400
Plant size	MW	1	10	80
(Production) solar cell efficiency	%	23	33	40
Optical efficiency	%	80	85	90
Cell cost per cell area	\$/cm^2	2 (silicon)	3 (III-V)	1.50 (III-V)
System efficiency	%	15	22	33
Capacity factor	%	32	32	32
CPV module cost	\$/m^2	160	90	80
Tracking cost	\$/m^2	70	35	25
Power-related balance-of-systems	\$/W$_p$	0.6	0.3	0.15
Area-related BOS other than land	\$/m^2	140	70	50
Indirect costs (% added to all above costs, not including land, to account for marketing and other indirect costs)	%	20	15	10
Annual O&M costs	\$/kWh-yr	.02	.01	.005
Total capital cost per AC W$_p$	\$/W$_p$	9.00	5.0	1.0

Tasks for CPV Technology R&D

1. CPV Cell Research and Development
2. CPV Receiver Research and Development
3. CPV Module Research and Development
4. System Analysis

4.2 Concentrating Solar Power Systems

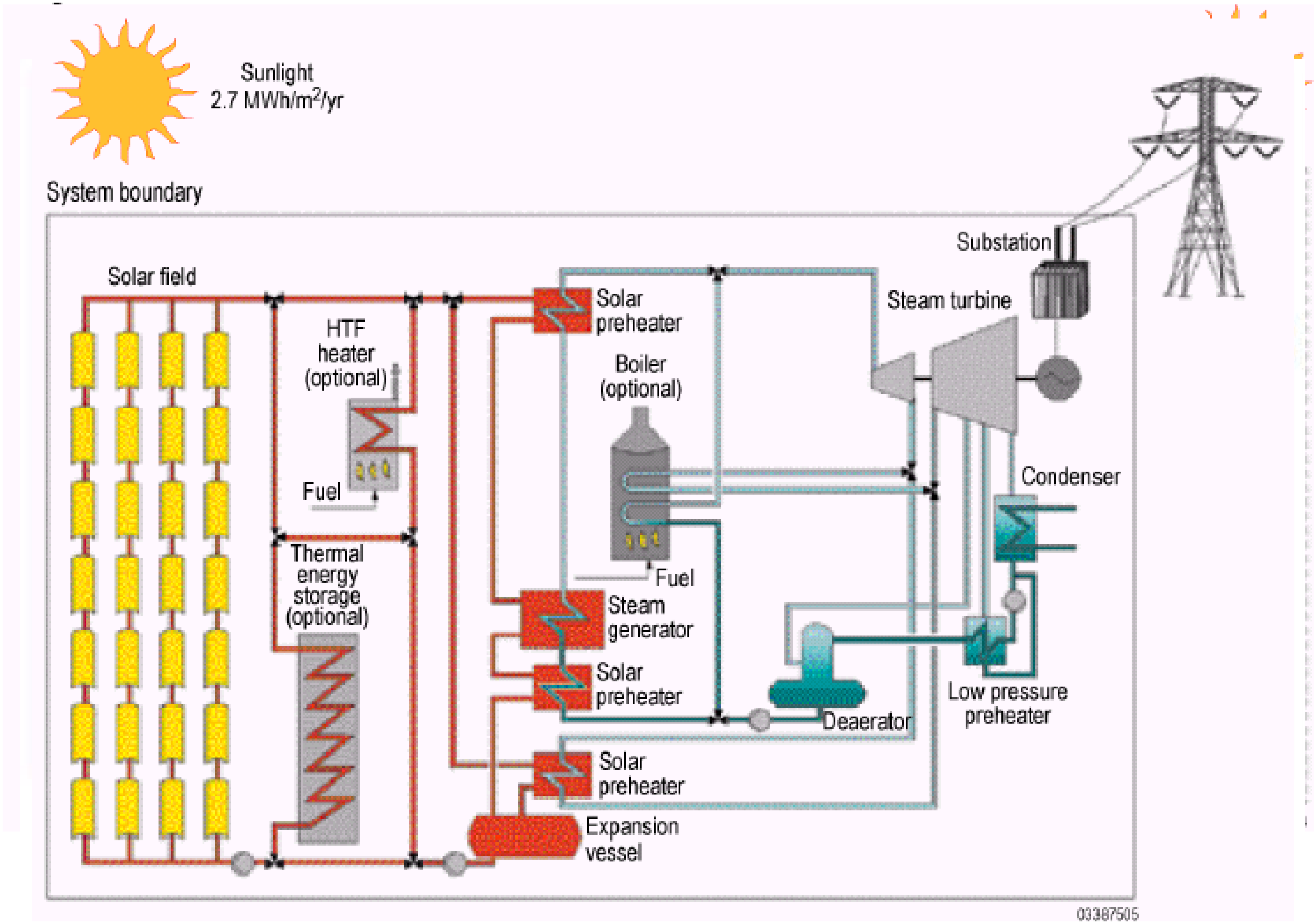


Figure 4.2-1. Schematic of a parabolic-trough system.

4.2 Concentrating Solar Power Systems

Goals:

Troughs

- Develop parabolic-trough power plant technologies capable of competing on a cost competitive basis with conventional fossil power technologies as dispatchable intermediate load generation in the wholesale bulk-power market (levelized energy cost [LEC] $0.04 to $0.06/kWh).

Towers

- Develop power tower technologies that will be cost competitive with conventional fossil power technologies as dispatchable intermediate-to-baseload generation in the wholesale bulk power market ($0.04–$0.06¢/kWh).

Dishes

- Develop dish-Stirling systems capable of competing in niche areas of distributed generation (short-term competition is diesel generators), grid support, remote and village power markets. Ultimately, bulk-power generation may be a market for these systems.

4.2 Concentrating Solar Power Systems

Tasks for Parabolic Trough

Table 4.2-1. Technical Targets: Parabolic Trough Power
(Solar-only operation at premium solar site)

Table 4.2-2. Technical Targets: Power Tower

1.

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3.

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Tasks

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Tasks for Dish-Engine/ Converter Technology R&D

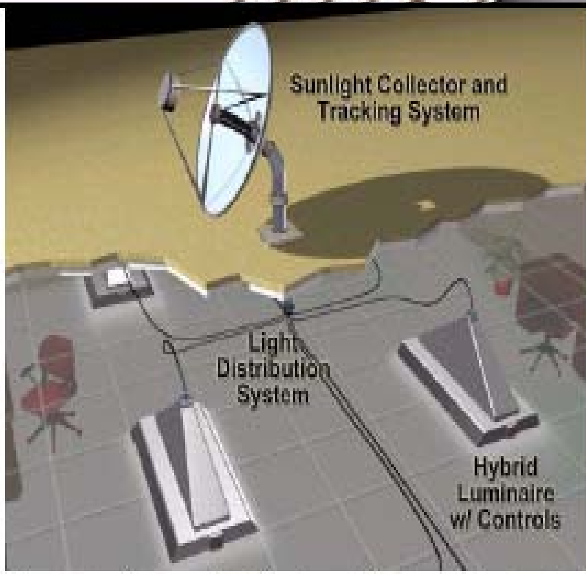
1. Perform Systems Analysis
2. Improve System Performance and Reliability
3. Develop and Test Advanced Components
4. Promote/Support Deployment by Industry

Table 4.2-3. Technical Targets: Dishes

Plant Characteristics	Units	Calendar year 2003	2007	2025
Solar Resource: Daggett, CA	kWh/m^2-yr	2800	2800	2800
Solar Collector				
Solar Aperture Area	m2	91	91	88
Projected Glass Area	m2	88	88	85
Reflectivity		0.92	0.94	0.95
Intercept Factor		0.95	0.97	0.99
Concentrator Weight	Kg/m^2	75	65	30
Power Conversion Unit				
Receiver Type		DIR	DIR	ADV*
Receiver Efficiency		0.90	0.90	0.95
Engine Type		KSE	KSE	ADV
Engine Efficiency		0.32	0.35	0.42
System Performance Parameters				
Capacity Factor				
Annual Solar Energy Production	$kWhrs/m^2$	575	627	754
Annual Total Energy Production	$KWhrs/m^2$	575	627	1095
Annual Solar Efficiency Net		0.20	0.23	0.26
Annual Capacity Factor		0.24	0.24	0.50
Levelized Energy Cost	$/KWhr	0.40	0.20	0.06

Considerations:
Hybrid receiver in 2025.

4.3 Solar Heating and Lighting



Basic HSL System

Prototype HSL collector mounted on ORNL's NTRC building

Photo of HSL laboratory being illuminated by distributed sunlight (left) and standard fluorescent lamps (right)

4.3 Solar Heating and Lighting

Goals:

- Develop low-cost passive solar water heaters for warm climates that will be cost-competitive with conventional technologies, with levelized energy cost (LEC) of 4-6¢/kWh. This represents a 25%–50% reduction.
- Develop low-cost active solar systems for solar water heating in cold climates and for combined building heating and cooling that have LEC of 6¢/kWh. This represents a 50%– 70% cost reduction, depending on application.
- Develop a low-cost hybrid solar lighting system that has LEC of 12¢/kWh, a reduction of 70% from the current cost estimate of the first system.

4.3 Solar Heating and Lighting

Tasks for Passive Solar Water Heating for Warm Climates

1. Durability
2. Building Codes
3. Manufacturing

Tasks for Active Cold Climate Water Heating and Active Solar Combined Heating and Cooling

1. Collector
2. Storage
3. Balance of System
4. System Integration

Tasks for Hybrid Solar Lighting

1. Collector
2. Fiber Optics
3. Balance of System
4. System Integration and Analysis

Table 4.3-2. Technical Targets[a] — Active Solar

Chara...	SWH[b]	Htg & Clg[c]
System		
Coll...		
Adm...		
Buil...		
Cus...		
Tota...		
LEC		
Comp...		
Coll...		
Sto...		
Bala...		
Insta...		
Mar...		
O&M		

a: Co...
b: Ty...
c: H... assumed in a southwest Sun Belt climate, assume Sacramento, CA, with I_{col} = 5.5 kWh/m²-day, at tilt of (lat-15°).
d: Glazed system: space heating and DHW only, no cooling.
e: Unglazed system, with space heating, DHW, and space cooling (radiative/convective heat rejection at night); ~6% net heating efficiency increased to 8% to account for the cooling savings.
f: Marketing cost taken as 25% of builder cost for SWH, and 15% of cost for space htg/clg system.

Table 4.3-3 Technical Targets — Hybrid Solar Lighting

Characteristics	2003 status	2007 goal
Energy displacement efficiency	52%–250%	70%–315%
Projected installed $/W_p$	$10/W_p$	$2.00/W_p$
Projected payback period (Sun Belt)	20 years	4 years
Projected relative lifecycle cost	$20,000	$5,000
Projected LEC savings	$0.41/kWh	$0.12/kWh
Projected system cost/m² collector area	$10,000/m²	2,000/m²
Delivered lumens/m² collector area	40,000 lum	50,000 lum
Projected cost of delivered lumens (peak)	$0.16/lum$_p$	$0.035/lum$_p$

Note: Energy displacement efficiency is the amount of electrical power displaced per unit incident solar power available.

4.4 New Concepts

Beyond the Horizon and Future Generation Photovoltaics:

- *Organic Solar Cells*
- *Dye-Sensitized Solar Cells*
- *Nanotechnology Solar Cells*
- *Third-Generation Technology*

Advanced Building Integrated Concepts:

- *AC Building Block*
- *PV/Thermal Hybrid*

Advanced Solar Conversion:

- *Solar-Thermal Hydrogen*
- *Direct Conversion*
- *Thermochemical Transport and Storage*

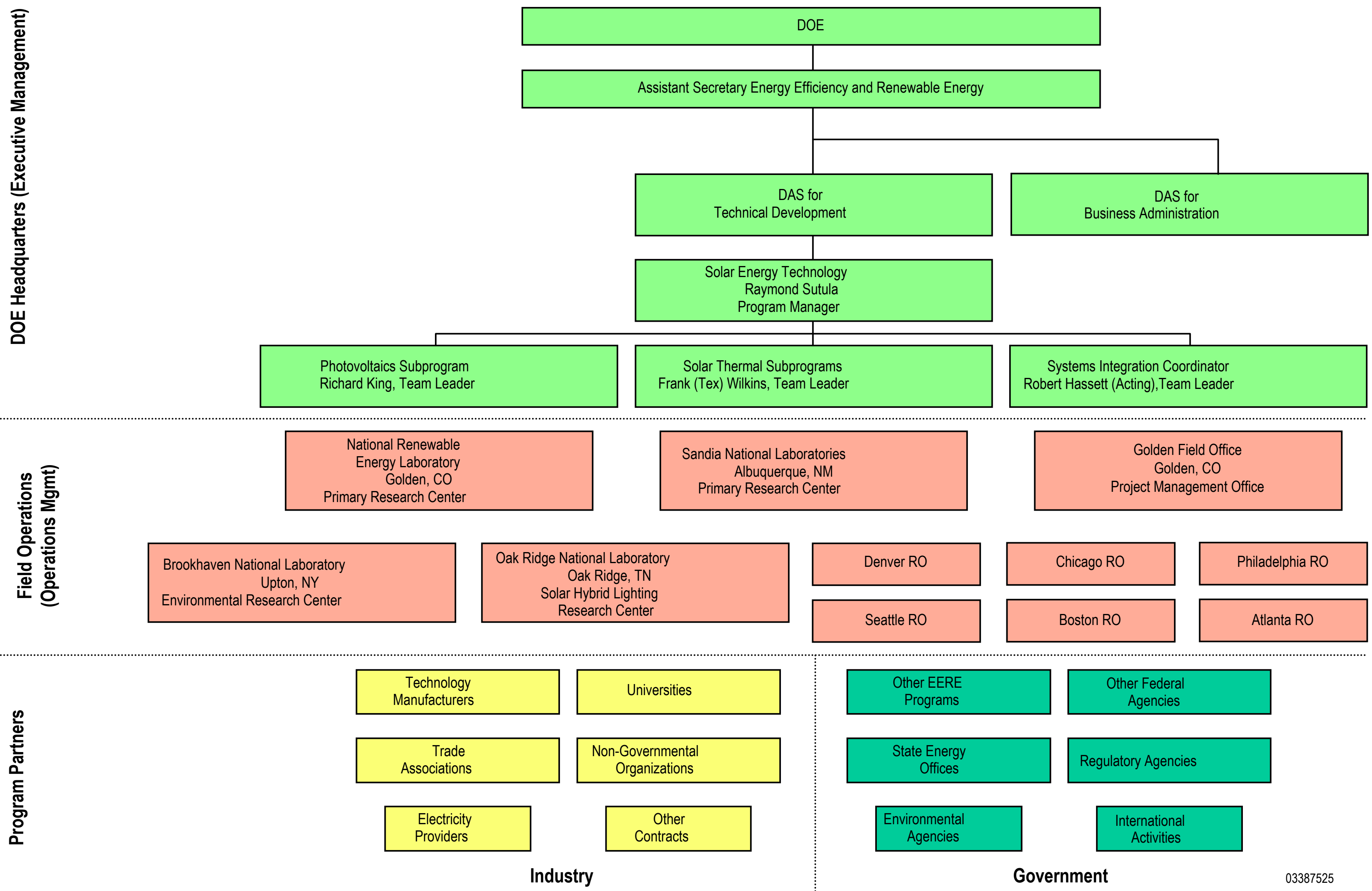
***None of these activities are presently along any of the Program's critical paths.

5.0 Managing the Solar Energy Program

- Overall Metric is Levelized cost of energy (LCOE)

- Long-Term goals
  – Photovoltaics @ $0.06/kWh ($1/watt)
  – Concentrating Solar Power @ $0.04-0.06/kWh (50% capacity factor)
  – Solar Hot Water @ $0.04-0.06/kWh ($1,300.00 installed)

5.0 Managing the Solar Energy Program



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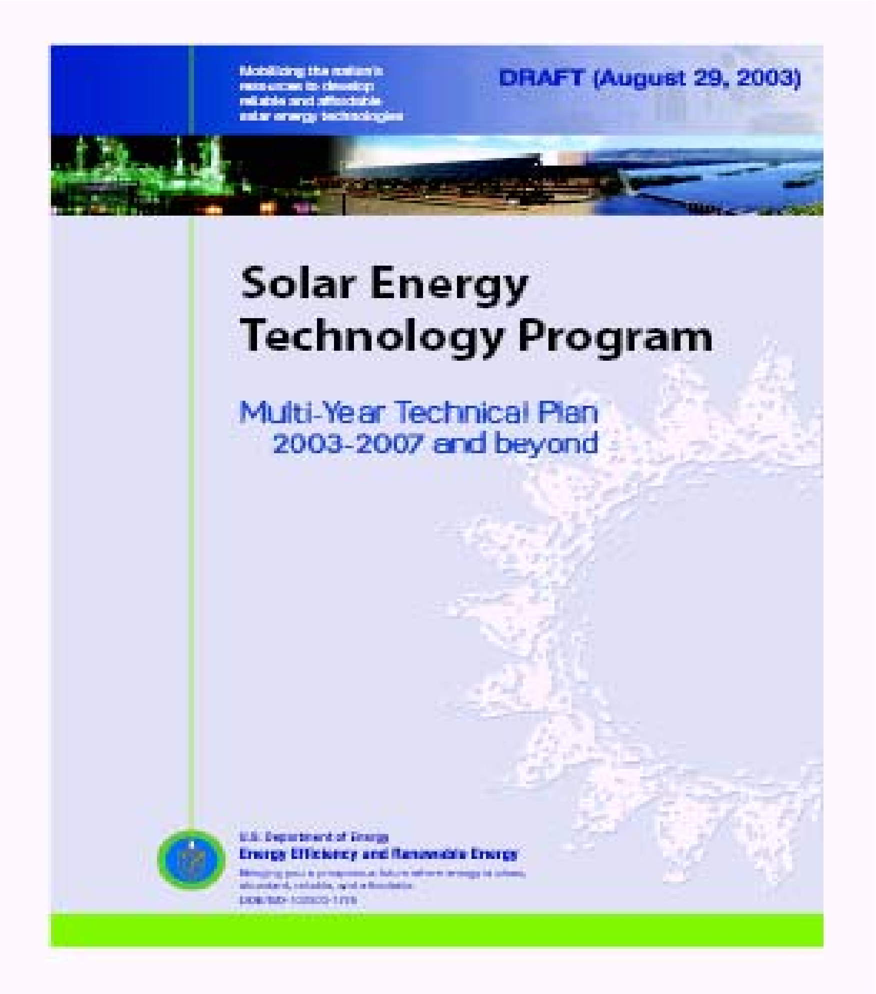
Solar MYTP Available



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